Changes in accessibility to emergency and community food services during COVID-19 and implications for low income populations in Hamilton, Ontario

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Abstract

In this paper we analyze the changes in accessibility to community and emergency food services before and during the COVID-19 pandemic in the City of Hamilton, Ontario. Many of these food services are the last line of support for households facing food insecurity; as such, their relevance cannot be ignored in the midst of the economic upheaval caused by the pandemic. Our analysis is based on the application of balanced floating catchment areas and concentrates on households with lower incomes (<CAD40,000, approximately the Low Income Cutoff Value for a city of Hamilton's size). We find that accessibility was low to begin with in suburban and exurban parts of the city; furthermore, about 14% of locations originally available in Hamilton closed during the pandemic, further reducing accessibility. The impact of closures on the level of service of the remaining facilities, and on accessibility, was disproportionate, with system-wide losses exceeding 40%. Those losses were geographically and demographically uneven. While every part of the city faced a reduction in accessibility, inner suburbs fared worse in terms of loss of accessibility. As well, children (age ≤ 18) appear to have been impacted the most.

Introduction

Food insecurity is defined as an "inadequate or uncertain access to a sufficient quantity and/or adequate quality of food" due to a household's financial limitations (Enns et al., 2020). This condition has been associated with reductions in nutritional outcomes (Bhattacharya et al., 2004; Kirkpatrick and Tarasuk, 2008; Olson, 1999) and negative physical and mental health impacts in children and adults (Elgar et al., 2021; Jones, 2017; Ramsey et al., 2011; Seligman et al., 2010; Stuff et al., 2004). Over at least the past four decades food banks and related services have become an essential line of defense against food insecurity in Canadian communities (Black and Seto, 2020; Holmes et al., 2018; Riches,

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2002; Tarasuk et al., 2020). In this respect, Canada is not unlike numerous other wealthy countries where a systematic dismantling of the welfare state took place in the intervening period (Tarasuk et al., 2014).

The emergence of COVID-19, the worst public health crisis since the 1918 flu pandemic, has exposed important social and economic fault lines, and pre-existing patterns of inequality appear to have been exacerbated. Along several other dimensions of stress (e.g., accessibility to health care facilities, Ghorbanzadeh et al., 2021; Pereira et al., 2021a), this seems to be the case for food insecurity as well (Laborde et al., 2020). According to Statistics Canada (2020a), in the early stages of the pandemic almost 15% of individuals reported living in a household that faced food insecurity; the risk of food insecurity was substantially higher for households with children. The difference between households with and without children was significant, and 11.7% of households with children indicated that "food didn't last and [there was] no money to get more" sometimes or often, compared to 7.3% of households without children; likewise, 13% of households with children indicated that they "[c]ouldn't afford balanced meals" sometimes or often, compared to 8.8% of households without children. Additionally, Men and Tarasuk (2021) report that about 25% of individuals who experienced job insecurity (a relatively common occurrence during the pandemic) also experienced food insecurity associated with COVID-related disruptions to employment, financial hardship, and use of food charity.

The impacts of food insecurity during the pandemic are alarming, since diet-related diseases, such as obesity, heart-disease, and diabetes, were already critical public health concerns in Canada prior to COVID-19 (Boucher et al., 2017). While emergency food services are not necessarily a stable solution to food insecurity and in fact may encourage a retrenchment of neoliberal policy (Wakefield et al., 2013), at least they can be argued to provide a resource of last instance to households in precarious situations (Bazerghi et al., 2016). As a mid-size city grappling with deindustrialization, Hamilton exhibits high rates of poverty and food bank use. As recently as 2019, the Hamilton Hunger Report (HFS, 2019) noted that food banks in the city recorded the highest number of visitors in the past 29 years; a rate of increase greater than population growth. Most troubling, approximately 40% of all visitors were children.

It is known that urban food environments, within which people make their daily food choices, are essential in influencing eating behaviours and health outcomes, based on factors such as food availability, ease of geographic accessibility and socio-demographic variations (Paez et al., 2010; Vanderlee and L'Abbé, 2017; Widener, 2018). However, while there is a wealth of literature that has examined the topic of geographic accessibility to healthy food through the "food desert" concept, there has been little research into accessibility to emergency and community food services. Previous work has explored differences in *accessing* food banks, such as how some households utilize food banks over short periods of time while others regularly utilize food banks as longer-term resource (e.g., Enns et al., 2020). In addition, transportation and locational considerations have been raised as key issues in food bank accessibility in previous qualitative research (Smith-Carrier et al., 2017). However, we are not aware of any research that has focused on estimating or capturing this geographic component of accessibility.

The study of place-based geographic accessibility is concerned with capturing the potential to reach destinations of value using the transportation network (Páez et al., 2012). Indeed, the Government of Canada's recent Food Policy (Agriculture and Canada, 2019) has made "access" to healthy food a priority for Canadian communities[^2] and previous survey research has suggested that such accessibility plays a key role in user satisfaction with food bank service delivery (Holmes et al., 2018). However, as with research into the prevalence of food deserts, accessibility to food banks is unlikely to be evenly distributed, and variation throughout a city can be expected due to transportation network characteristics and the spatial distribution of service locations and the population they are meant to serve. Furthermore, policy responses to the COVID-19 pandemic likely have added to the distress of vulnerable households. Non-pharmaceutical interventions during the pandemic involving restrictions in mobility have increased the friction of travel, in particular by transit on which low income populations are more reliant (e.g., DeWeese et al., 2020). At the same time, the pandemic has created additional stress for the operators of food banks through disruptions in the supply chain (e.g., McKay et al., 2021) as well as concerns surrounding the delivery of service in safe conditions and possible cancellation of food service programs.

For this study, we aim to look at how the landscape of food banks and related services (e.g. low-cost or free meal service providers) available in Hamilton, Ontario, changed during the pandemic. Did the number of open food bank services diminish? If so, what was the accessibility to food banks before the pandemic from the perspective of low income households, and how has it changed during the pandemic with respect to geographic access and congestion at remaining sites? And finally, who are most likely to have been impacted by changes in the accessibility landscape? This paper first looks at the distribution of food banks and related services before and during the pandemic. Then, we use the balanced floating catchment area approach of Paez et al. (2019) to investigate the accessibility situation. For this, we adopt a fully disaggregated approach based on parcel-level data. Socio-economic and demographic data are drawn from the latest Census of Canada (2016), whereas travel information is from the most recent regional travel survey from 2016. This paper follows reproducible research recommendations (see Brunsdon and Comber, 2020), and the research was conducted using open source tools for transportation analysis (Lovelace, 2021). The code and data necessary to reproduce the analysis are available in a public repository (see Supplemental Material).

Food Insecurity and Food Bank Use in Canada

Food insecurity is the inability to acquire and consume an adequate amount or good quality food, leading to inadequate nutrient intake (Kirkpatrick and Tarasuk, 2008) and poorer physical and mental health outcomes (Ramsey et al., 2011; Seligman et al., 2010; Stuff et al., 2004). In this regard, food insecurity is a major population health concern, particularly among Canadians at socio-economic disadvantage (Bazerghi et al., 2016). Official government surveys such as the Household Food Security Survey Module (HFSSM), the Canadian Community Health Surveys (CCHS), the Longitudinal and International Study of Adults (LISA), and official classifications determined by Health Canada in relation to socio-demographic variables offer some insight into food insecurity in Canada (Gundersen et al., 2018; Kirkpatrick and Tarasuk, 2008; Tarasuk and Vogt, 2009).

Nationally, it has previously been found that food insecurity impacts approximately 12.3% of Canadian households (Tarasuk et al., 2014) using data from the 2011-2012 CCHS. Using the same data, Tarasuk et al. (2019) found higher odds of food insecurity amongst households relying on social assistance, those without a university degree or with children under the age of 18, and individuals that lived alone, renters, and those identifying as Aboriginal. While surveys revealed that only 20 to 30 percent of those experiencing food insecurity were found to frequent food banks in Canada (Tarasuk et al., 2014), pre-pandemic research from Ottawa (Enns et al., 2020) and Vancouver (Black and Seto, 2020) suggests that long-term users tend to be older, have health or mobility challenges, live in large households, and are less likely to have employment income. In terms of geography, previous research conducted at the provincial scale using data from the 2011-2012 CCHS found that the prevalence of food insecurity ranged across the country from 11.8% of households in Ontario to 41% of households in Nunavut (Tarasuk et al., 2019).

Food banks - sometimes also referred to as 'food pantries' and 'food shelves' - originated as a community response to aid those with inadequate food by voluntarily offering them meals and ingredients (Loopstra and Tarasuk, 2012; Riches, 2002). Although in their origin food banks were meant to be provide a temporary solution to accommodate those in hunger due to job retrenchments and economic downfalls since the 1980s, over time many have evolved into a community practice to secure food supplies for those in need (Loopstra and Tarasuk, 2012; Wakefield et al., 2013). In Canada, the number of food banks has steadily increased in the past few decades (Wakefield et al., 2013). The largest database of food banks and their use comes from the non-profit association Food Banks Canada (FBC), which conducts an annual assessment through its affiliated members. FBC's 2018 Hunger Count report (FBC, 2018) (the most recent available) listed 1,830 member food banks across the country, and found that Canadians visited food banks 1.1 million times in March of 2018. Of those accessing food banks, certain population characteristics tend to be over-represented compared to national totals from the 2016 Canadian Census of Population. According to FBC's 2018 data, single-adult households represent 45% of those utilizing food banks despite making up 28% of Canada's population, 19% are single-parent households (compared to 10% nationally), and 35% of those using food bank services are children aged 0-18 even though their share of Canada's national population is approximately 20%. In addition, 59% of households accessing food banks list social or disability assistance as their primary source of income.

In the United States, economic stress caused by the COVID-19 pandemic, rising unemployment rates, and changes in poverty levels have disrupted the food environment and led to higher rates of food insecurity (Niles et al., 2020). Pandemic-related food security studies in the US have found a substantial increase in households experiencing food insecurity for the first time, and also in households experiencing more severe food insecurity than before (Niles et al., 2020; Wolfson and Leung, 2020). Considering the negative mental and physical health effects, increases in food insecurity rates due to the onset of COVID-19, signal a change in the food environment with potential damages to population health during the course of the pandemic and beyond (Niles et al., 2020).

Canada has also seen an increase in the number of households living in food insecurity due to the COVID-19 pandemic. Survey results from Statistics Canada from May of 2020 suggest that 14.7% of the population was living in food insecurity in the past 30 days, up from 10.5% in 2017-2018 (Statistics Canada, 2020a). Recent data from FBC (FBC, 2020) showed that 52% of member food banks reported an increase in usage in March of 2020 when initial lockdown restrictions were put in place across much of the country. The pandemic also created significant staffing issues with 42% of food banks reporting a reduction in volunteers. However, 53% of food banks later reported a decrease in use into the summer of 2020 which FBC members attributed to emergency financial support programs from the federal government. Nevertheless, some of these benefit programs were temporary. Although more recent statistics on food bank use in Hamilton in 2020 and 2021 are not yet available, data from the Daily Bread Food Bank (DBFB, 2020) in neighbouring Toronto for August 2020 shows visits climbing 51% year-over-year in that city, which suggests that many households in Hamilton are likely to turn to food bank services to meet their needs.

Beyond traditional conceptualizations of food banks as providers of emergency food assistance, other community food services also play an important role in decreasing food insecurity. The scope and objectives of food banks can vary by region and by country, and these organizations can include not only prepared meals and aliments for emergency food supply, but also shared spaces to connect in community gardens and community kitchens (Wakefield et al., 2013). However, the efficacy of these programs in reducing food insecurity differs by the type of service offered. For example, previous qualitative research in the Toronto region has questioned the capacity of community kitchens to improve the food security of low-income households due to their limited scale of operations, and unsubsidized kitchens were found to be particularly inaccessible to to families living in severe poverty (Tarasuk and Reynolds, 1999). However, other food access options such as no-cost or low-cost meals provided through community meals or congregate dining play an important role in decreasing food insecurity. Research in Minnesota found that seniors experiencing food insecurity valued congregate dining for providing affordable meals and a space for social gathering (Oemichen and Smith, 2016). Furthermore, because seniors paid for the meal, there was no stigma attached to the use of these services compared to traditional food-purchasing assistance such as the Supplemental Nutrition Assistance Program.

While previous research has examined the characteristics of individuals and households accessing emergency and community food services, the locational or transportation accessibility aspect of food bank access is not well understood. A wealth of literature examining the food desert concept suggests that, in addition to socio-economic and demographic factors, location and transportation networks play a key role in a household's accessibility to healthy foods (Paez et al., 2010; Vanderlee and L'Abbé, 2017; Widener, 2018). For food banks specifically, previous qualitative research in Ontario by Smith-Carrier et al. (2017) has noted that "transportation can be challenging, particularly if the food bank is situated in a remote location" (p. 32). Particularly, it appears that participants experience challenges with the "inordinate amount of time necessary to obtain food, and difficulties associated with transportation" (p. 39). Users of food banks, according to this research, rely on a variety of modes of transportation to access services. Consequently, the location of facilities matters; in the words of an interviewee: "I wish it [the food bank] was a little more centrally located. Because if I didn't have a bike I'd have to walk it all the way out there and back. I wonder about people who don't" (p. 39).

To offer greater insight into the role of transportation and location in food bank accessibility, this research examines how geographic accessibility to food banks and food services changed in Hamilton during the COVID-19 pandemic.

Methods and Materials

Methods

For the research in this paper we adopt the balanced floating catchment area approach of Paez et al. (2019). This method for estimating accessibility is a form of the widely-used two-stage floating catchment area method (Luo and Wang, 2003; Radke and Mu, 2000). Floating catchment areas are used to estimate accessibility when there are potential congestion effects, and operate by calculating first the *demand* for spatially distributed services. The demand (usually the number of people who require a service) is used to calculate a level of service. In a second step, the level of service is allocated back to the population. Demand and level of service are allocated using some form of distance-decay to embody the geographical principle that, given a choice, people prefer to travel less than more when reaching destinations.

More formally, the first step of this method is as follows:

$$L_j = \frac{S_j}{\sum_{i=1}^{n} P_i w_{ij}}$$

where S_j is the level of supply at location j, in simplest terms whether a service point is present (i.e., $S_j = 1$) or not (i.e., $S_j = 0$); P_i is the population at location i that demands the service; and w_{ij} is a weight, typically a function of the distance between locations i and j. L_j is the level of service at location j and it is the inverse of the number of people that need to be serviced.

The second step in this process is then summing the level of service that each population unit can reach, according to the distance-decay weight:

$$A_i = \sum_{j=1}^{J} L_j w_{ji}$$

where A_i is the accessibility to the service, which is in the same units as the level of service: as the inverse of the population being serviced. When the population being serviced is low accessibility is high (i.e., there is little competition for the service), and viceversa.

Floating catchment area methods are prone to overestimation of the population and the level of service due to multiple-counting. The population at P_i is allocated to *every* service point j for which $w_{ij} > 0$. Similarly, the level of service at LOS_j is allocated to *every* population point for which $w_{ji} > 0$. This inflation effect has been known for several years, and several modifications have been proposed to mitigate it (Delamater, 2013; e.g., Wan et al., 2012). A definitive solution to this issue was presented by Paez et al. (2019). In order to avoid the multiple-counting in the summations, the population and the level of service need to be allocated *proportionally.* This is achieved by standardizing the weights as follows:

$$w_{ij}^{\text{st}} = \frac{w_{ij}}{\sum_{i=1}^{n} w_{ij}}$$

and:

$$w_{ji}^{\text{st}} = \frac{w_{ji}}{\sum_{j=1}^{J} w_{ji}}$$

The standardized weights satisfy the following conditions:

$$\sum_{i=1}^{n} w_{ij}^{\text{st}} = 1$$

and:

$$\sum_{j=1}^{J} w_{ji}^{\text{st}} = 1$$

Since the population is allocated proportionally, its value is preserved:

$$\sum_{i=1}^{n} P_i w_{ij}^{\text{st}} = P_i$$

as is the level of service:

$$\sum_{j=1}^{J} L_j w_{ji}^{\text{st}} = L_j$$

Study Area

With a population of around 540,000, the City of Hamilton is the fourth largest city in Ontario. It has historically been home to major manufacturing industries but de-industrialization that has occurred over the past several decades has led Hamilton to become one of the most highly divided cities in Ontario, with a significant proportion of its residents living at or below Canada's poverty level (DeLuca et al., 2012; Jakar and Dunn, 2019; Latham and Moffat, 2007). The Hamilton Community Foundation (HCF, 2018) reported that based on the Low-Income Cut-Off, Hamilton recorded a poverty rate of 16.7% in 2016, which was well above the average rate of Ontario (13.7%) and the average national rate (12.8%). According to data from Hamilton Food Share (HFS, 2019), approximately 23,000 individuals accessed food banks in the city in March of 2019. Within this total is 9,125 visits by children (minors up to 18 years old), up from 8,278 the year before. Feed Ontario, the province's largest collective of hunger-relief organizations, found that on a per-capita basis, the level of need in the inner core of central Hamilton was second highest in Ontario (FO, 2019).

Geographically, the "old" City of Hamilton was amalgamated with several of its surrounding municipalities in 2001, with the city now featuring a mix of urban, suburban, exurban, and rural areas. Lower-cost housing proximate to the city's industrial north end has traditionally attracted immigrants and less-affluent residents compared to the city's wealthier suburbs. However, the decentralization of population from the inner core has led to challenges in transit connectivity to amenities and services and the proportion of auto users compared to transit users remains very high (Behan et al., 2008; Topalovic et al., 2012). In addition, the city is separated geographically by the Niagara Escarpment. With sections of rocky cliff that approach 100m in height, the escarpment presents a significant challenge for promoting active travel and transport connections between "mountain" and "lower city" neighbourhoods. Taken together, the high level of food need, population locations, and transportation network characteristics combine to inform spatial accessibility to food banks and food services in the city.

Data

Data have been prepared for sharing as a data package available in the Supplemental Materials. The contents of the data package are described next.

Statistics Canada

Population and income statistics for 2016 were retrieved at the level of Dissemination Areas (DAs) using the package `cancensus` (von Bergmann et al., 2021). DAs are the smallest publicly available census geography in Canada. Income data corresponds to the count of households by different total income groupings.

Origins: Residential parcels

We converted all recorded residential land parcels in the City of Hamilton to points on the road network. Each point includes information about the number of residential units in the parcel. Next, we define low-income households as those having a total income of less than CAD40,000, which is approximately the mid-point of the low income cut-off (LICOs) for families in Canadian cities with populations greater than 500,000 in 2016, to match other Census data (Statistics Canada, 2020b). We then "populate" each residential unit with the probability of being a low-income household based on the counts of households by income groups in the DA in which the parcel is located. While this method assumes a constant probability of low-income household status for all residential units in a DA, the parcel-level analysis affords a high level of spatial disaggregation for the accessibility analysis.

Destinations: Food Banks and Food Service Locations

The locations of emergency and community food services were obtained from the Hamilton Public Library's Food Access Guide (HPL, 2021). The guide was updated in April of 2021 to indicate any change affected on the services due to the pandemic. This includes modified business hours, a need to make reservations before frequenting, and locations that have completely shut down in consequence. Table 1 defines each service type and the number of locations pre- and during the COVID-19 pandemic. While some food bank services have a specific target population, such as prioritizing families with young children aged between 0 and 3 or accepting only those providing proof of low-income status through housing and utility statements, all the food services indicated below are designed to accommodate those in need of food at zero to low cost. With our focus on food banks and food services that offer free or low-cost meals at particular locations, we first removed services such as Meals on Wheels and other food access services such as food box, community kitchens, student nutrition programs, and shopping and transportation. With some providers offering different food services at the same location (e.g. food bank with free and community meal services), and some of these services closing after the onset of the COVID-19 pandemic, we opted to geocode based on the service type. On the other hand, two free meal services held on different days at the same location were collapsed into a single service point for the accessibility analysis. Additional details on the operations of individual facilities is not publicly available and with the changes in operations it proved unfeasible to collect it. For this reason, the analysis to follow is of accessibility to the location of food banks and services, but not to specific services (e.g., breakfasts vs. food boxes).

Routing and travel time tables

Travel time tables for three modes (car, transit, walking) were computed using the parcels as the origins and the locations of the community and emergency food service locations as the destinations. For routing, the package `r5r` (Pereira et al., 2021b) was used with a network extract for the City of Hamilton from OpenStreetMaps and the General Transit Feed Specification (GTFS) files for

Table 1: foodbank and Food Service Information.

Type	Description	Locations Pre-COVID	Locations During COVID	Additional Notes
Congregate Dining	Congregate and dining programs provide low-cost meals that are enjoyed in a community setting. Transportation may be provided	7	2	One remaining location reduced hours during COVID
Community Meals	No-cost programs often run by volunteers that organize suppers, lunches or other get-togethers that give community residents an opportunity to meet one another in a friendly and informal atmosphere while sharing a meal	11	9	NA
Food Banks	Food Banks and Emergency Food programs provide individuals and families with grocery items free of charge	26	25	One remaining location reduced hours during COVID while 4 others moved to appointment only
Free Meals	Meals are provided free of charge in the community through volunteer labour and donations	9	5	One remaining location reduced hours during COVID
Low-Cost Meals	Restaurants, cafeterias and other eating establishments operated by hospitals, senior centers or other organizations which provide reduced-cost meals for low-income people, older adults or other targeted individuals.	2	1	The remaining location reduced hours during COVID

the Hamilton Street Railway, the local transit operator, as well as for Burlington Transit, which operates some service in the city. For transit routing purposes we used maximum travel time values of 300 min and a 2,000 m cap on walking distance: any destination that exceeded these thresholds was ignored. The departure time used for routing was 8:00AM on March 30, 2021 to reflect transit service around the morning service peak on a typical Tuesday.

Transportation Tomorrow Survey

We used the Data Retrieval System of the Transportation Tomorrow Survey (TTS)[1] to download cross-tabulations of: 1) primary mode of travel per trip by income by place of residence; and 2) age by income by place of residence. These data are from the 2016 Survey (the most recent available). The data are geocoded at the level of Traffic Analysis Zones (TAZ) using the most recent zoning system from 2006 and expansion factors are applied to weight the trips . Each parcel point is populated with the proportion of trips by three modes of travel: car (as driver or passenger), transit, and walk.

Expected Travel Times

Once we obtained travel time tables with population (number of households) and proportion of trips by mode, we calculated the expected travel time *ett* from each parcel i to a food bank or food service location j as follows:

$$ett_{ij} = p_i^c \cdot tt_{ij}^c + p_i^t \cdot tt_{ij}^t + p_i^w \cdot tt_{ij}^w$$

where p_i^k is the proportion of trips by mode k in the TAZ of parcel i, and tt_{ij}^k is the travel time from parcel i to the food bank. In other words, the expected

[1]http://dmg.utoronto.ca/

travel time reflects the weighted average of travel times to the food bank, with the weights given by the expected modal split of trips made by low-income households in the TAZ per the TTS data.

Results and Discussion

Figure 1 shows the location of food banks and services in the City of Hamilton and their status. Before the pandemic there were 58 of which 14 (24.14%) closed during the pandemic. As shown in the figure, food services tend to be predominantly located in the central parts of the city. This is not surprising: population density is high there, and it is also the part of the city where lower income households are more numerous in absolute and relative terms (see Figure 2). Alas, this is also the part of the city where most of the closures during the pandemic happened.

To implement the accessibility calculations, we must select a distance-decay function. In this task we find limited support in the literature, which is mostly silent on the travel patterns of people who visit food banks and community food services. For this reason, we opt for a simple cumulative opportunities function as follows:

$$w_{ij} = w_{ji} = \begin{cases} 1 & \text{if } ett_{ij} \leq \delta \\ 0 & \text{otherwise} \end{cases}$$

where ett_{ij} is the multimodal expected travel time as described previously, and δ is a travel threshold. When the expected travel time exceeds this threshold, a facility is no longer considered accessible. Moreover, the weights are standardized for the balanced floating catchment area approach.

Figure 3 shows the results of conducting a sensitivity analysis of the system-wide accessibility as we vary the threshold (considering the situation before the pandemic). There is a clear pattern whereby more strict values of δ are associated with higher levels of system-wide accessibility: while increases in accessibility that result from decreases in the travel time window might seem counter-intuitive, this is a result of lower *congestion*, since fewer households are serviced and thus competition for the same resources is more limited. System-wide accessibility declines with higher values of δ: as more households are serviced, congestion grows and the level of service declines, although this happens at a declining rate. We are not aware of any research that explains how long people are expected to travel for food banks, but we note that in developing countries, accessible sources of drinking water are those that can be reached in less than 30 minutes (round trip, see UNICEF-WHO, 2019). There is no reason why people in affluent countries should be expected to spend more time travelling for a basic necessity such as food. Accordingly, we adopt a 15-minute threshold for the analysis (representing a one-way trip). This threshold is also approximately where the rate of change in accessibility slows down.

Using the 15-minute threshold, we find that the system-wide accessibility (interpreted as a provider-to-population ratio) was 0.078 (food banks/service

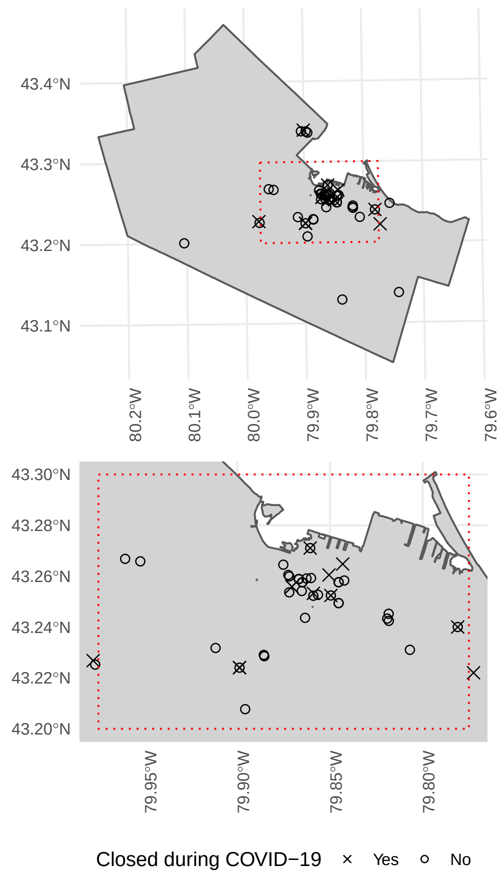


Figure 1: Location of food banks/services and operation status; the dotted box is an inset of the central part of the City of Hamilton

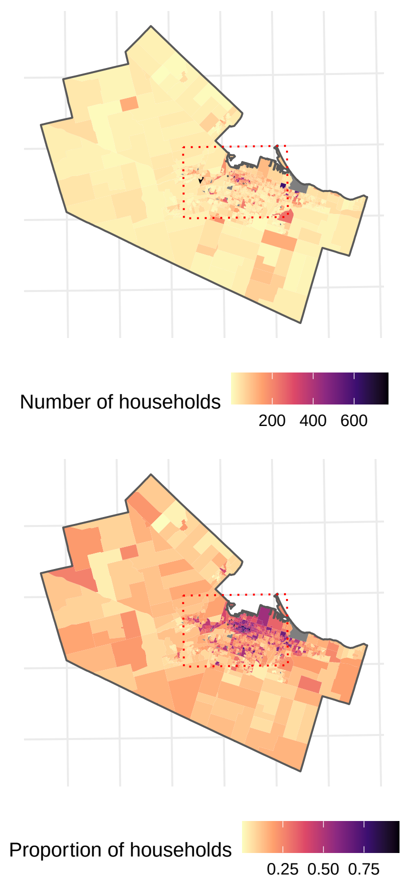


Figure 2: Number and proportion of households with incomes less than CAD40,000.

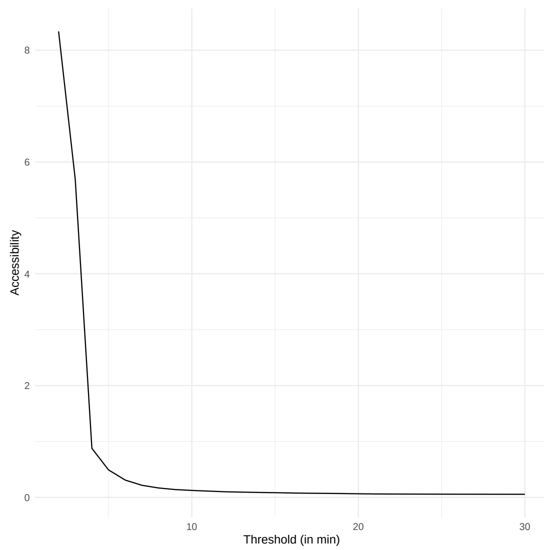


Figure 3: Accessibility as a function of threshold

locations per low income household in the city) before COVID-19, but declined to 0.048 during the pandemic. It is striking that although almost 76% of food facilities remained in operation during the pandemic, there was a loss of accessibility greater than 39%, suggesting the location of emergency and community food services plays an important role in serving those in need.

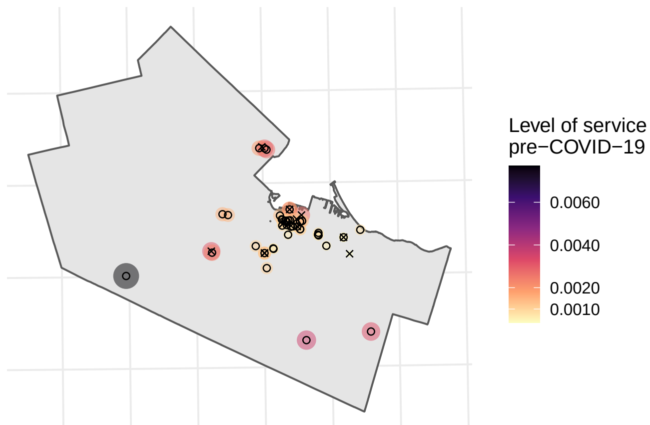
Turning to the location of individual facilities, the levels of service offered before and during the pandemic are shown in Figure 4. The level of service is functionally the inverse of the number of low-income households in the travel-mode weighted travel time catchment area of the facilities (this is because $S_j = 1 \forall j$, i.e., each location represents a "capacity" of 1). Higher values mean that a facility is expected to service fewer households. Conversely, lower values indicate greater congestion.

The general pattern of the levels of service is similar before and during the pandemic, with lower values in the center of the city where low-income households exhibit multimodal trip patterns that favour proximate service locations. Three more peripheral facilities towards the south of the city have moderate levels of service, presumably because they are expected to service relatively suburban/exurban populations generally reliant on automobiles for travel. During the pandemic, however, the levels of service dropped, in some cases quite substantially. The pattern of the losses in level of service, moreover, is not uniform. The upper pane of Figure 5 shows that the peripheral facilities in the suburban/exurban parts of the city saw major declines during the pandemic as more urban locations closed and demand increased for the remaining locations. Further, the inset map shows that the levels of service also deteriorated in the central part of the city. However, the loss of level of service was not as large in the core (where most of the food banks/services are found), but instead was more marked in the inner ring around the core, where facilities may have faced greater demand from both central city and suburban populations after the closure of service locations during the pandemic.

To further elucidate this issue, we now turn to the results of the accessibility analysis. As with the level of service of individual facilities, the general pattern of accessibility before and during the pandemic is similar. Figure 6 reveals that, compared with the outer rural zones, the more urban zones of the city generally exhibit higher accessibility to food banks and food service locations. However, the pattern is not particularly smooth - this is largely attributable to the weighting of travel times by mode of transportation according to the trip patterns of low-income household respondents captured by the TTS. For example, in zones where low-income households make a high proportion of trips by walking, access to food bank locations by walking is afforded a concomitantly high weight in our calculations of travel time compared to transit or car travel. From this, highly-accessible locations result from a mix of characteristics: low-income households in locations where travel options that align with zonal modal split are available to connect them to food bank locations with high levels of service within 15 minutes. This seems to track with the experience of some users of these services, as reported by Smith-Carrier et al. (2017).

We find that the accessibility landscape deteriorated substantially during the pandemic, with accessibility dropping on average by almost 38%, but with large variations: some zones experienced changes in accessibility of only about 8%, whereas the most affected zone saw a loss of accessibility of almost 96%. Figure 8 shows the changes in accessibility. Every zone is worse off after the closure of facilities during the pandemic, but some parts of the city seem to have been particularly affected. To better highlight these changes, we used a local indicator of spatial autocorrelation (Anselin, 1995) to explore the pattern of change in accessibility. Twenty-four TAZs are flagged as having significantly large losses of accessibility (at $p \leq 0.10$, without correcting for multiple comparisons). Those zones are highlighted in the figure, where it can be seen that they form more or less compact neighborhoods. Remarkably, the largest significant drops in accessibility are not downtown, but located in two cases in the industrial north of the city, in one case in an inner suburb above the escarpment, and lastly in a more suburban/exurban region in the south-west.

For the more suburban clusters of zones, the decrease in accessibility is derived from the closure of locations throughout the city reachable by car. In the cluster of central suburban zones for example, low-income households in the outer ring of zones that exhibit medium to high decreases in accessibility within this cluster appear to be largely auto-dependent in their tripmaking, which each each exhibiting between 85-100% of their modal split for car trips. This results in the parcels within these zones having a large number of potentially accessible locations in the travel time matrix. But by extension, the change in accessibility over the pre- and during-COVID-19 time periods is affected not only by the closure of service locations proximate to the zones, but also the locations in the central city. The zone with the greatest decrease in accessibility within this



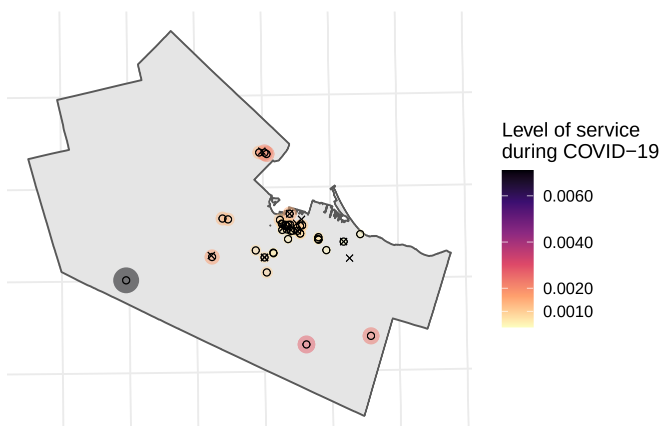


Figure 4: Levels of service at each facility pre-COVID-19 (top panel) and during COVID-19 (bottom panel).

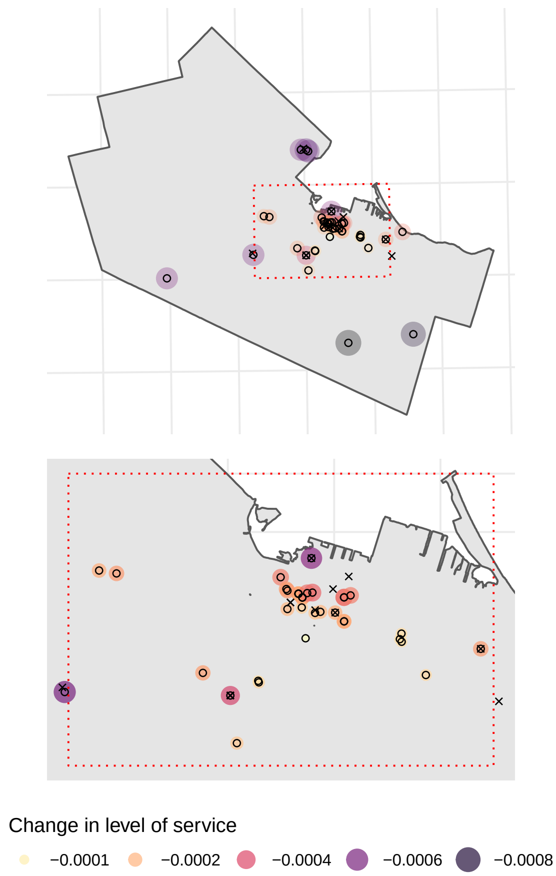


Figure 5: Changes in levels of service at each facility from pre-COVID-19 to during COVID-19.

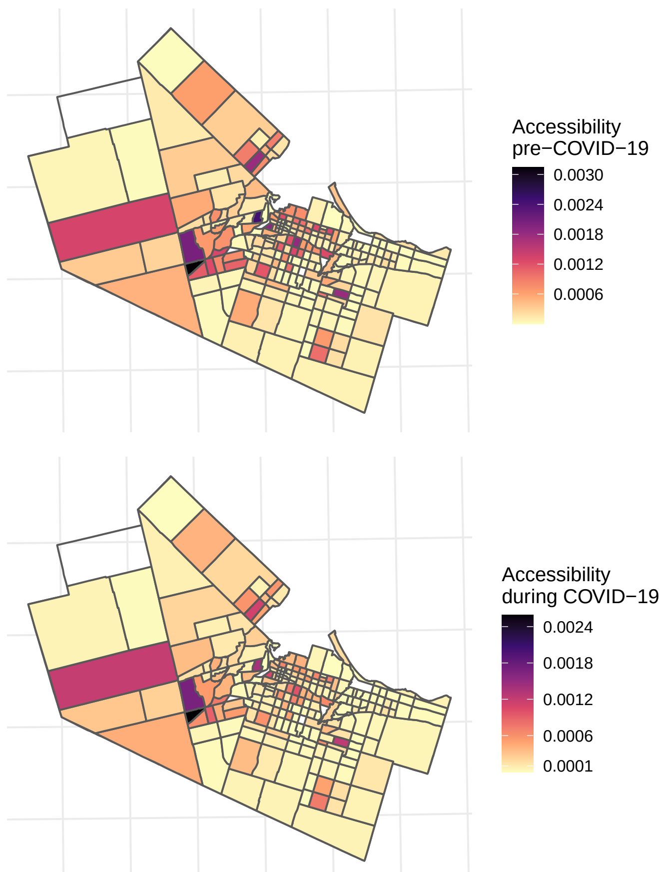


Figure 6: Accessibility by traffic analysis zone pre-COVID-19 (top panel) and during COVID-19 (bottom panel).

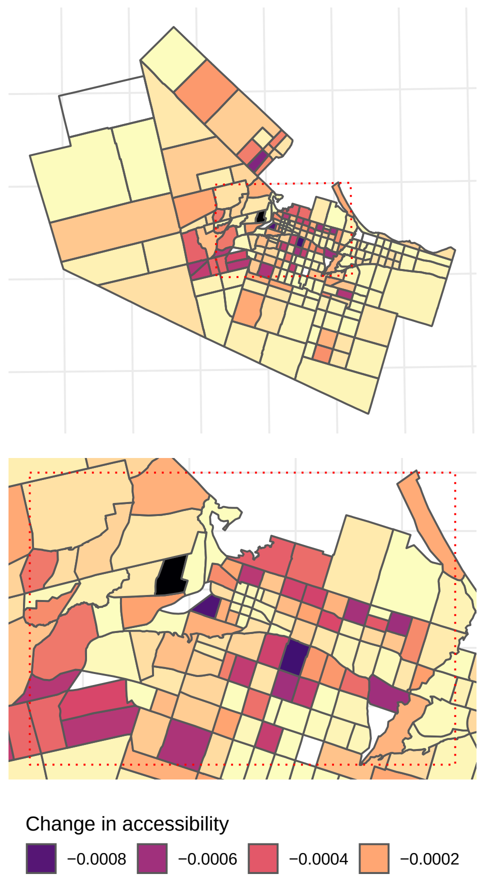


Figure 7: Changes in accessibility from pre-COVID-19 to during COVID-19.

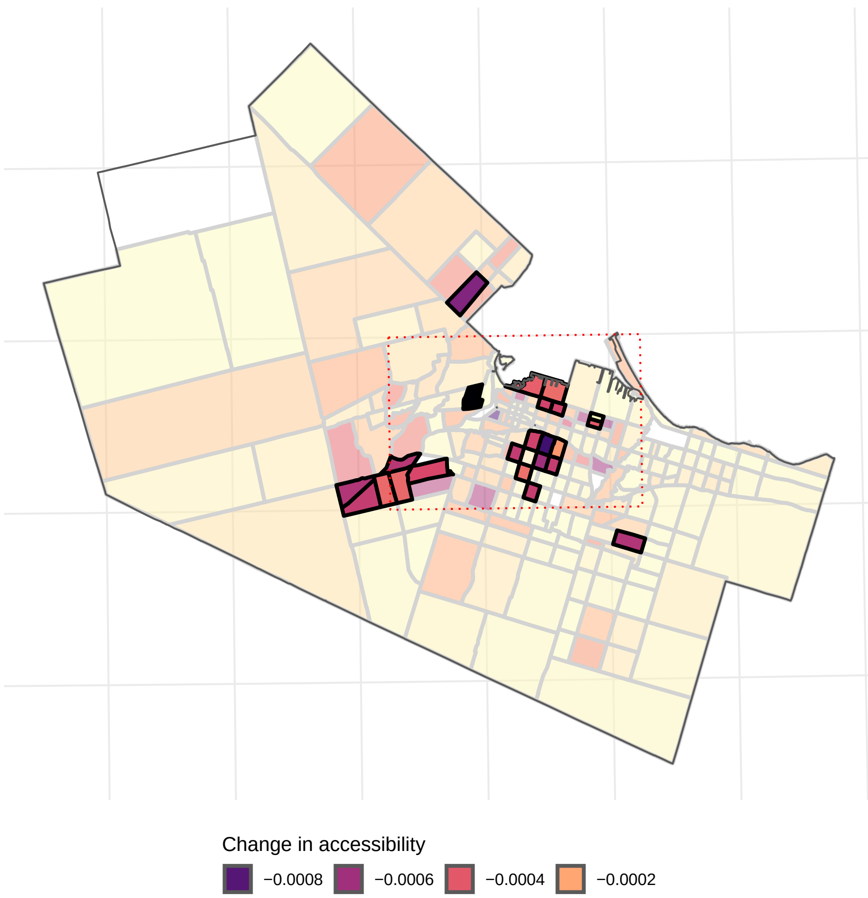


Figure 8: Changes in accessibility from pre-COVID-19 to during COVID-19. Highlighted areas had significantly large changes in accessibility according to Local Moran's I.

cluster (-0.0009) has a high rate of car trips and connects to the most food bank locations in total as well as those that stayed open or closed.

In the cluster to the south-west, the decrease in accessibility is predominately driven by the closure of a high level-of-service Community Meals provider. However, like the more central suburban zones, low-income households within this cluster are also between 90% to 100% auto-dependent in their tripmaking in the TTS. The story is similar for the zone located in the north-west that exhibits the greatest decrease in accessibility. Here, low-income households responding to the TTS conducted 100% of their trips by car and, as a result, dwellings within this zone have access to the second-highest number of food bank and service locations within 15 minutes. However, this also means zonal accessibilities are greatly affected by the number of closures throughout the city. Finally, in the city's north end and north-east zones, low-income households exhibit a mixture of tripmaking behaviour in the TTS. Households in some zones take transit more often and one zone in particular has 100% of its trips by walking. For these zones, the decrease in accessibility tends to be a product of the closure of several inner-city food bank and service locations reachable by multiple modes.

Just as the effects of the closures appear to have been uneven in space, they also seem to have had different impacts on various population segments. Using data on low income individuals by age drawn from the TTS, Table 2 shows the estimated number of people in each age group by their level of accessibility before and during the pandemic. Here, it is important to note that the quartiles are relative: people in the top 25% of accessibility still have lower accessibility during the pandemic than before. In reality, every population group is worse off during the pandemic in terms of their accessibility to food banks and services in the City of Hamilton. However, some age groups were affected more. As seen in the table, the distribution within quartiles for adults changed only slightly, and in fact there are fewer adults in the bottom three quartiles as some found themselves in the (deteriorated) top quartile of accessibility during the pandemic. The story is different for seniors, a greater number of whom are now in the third quartile, due to a combination of seniors facing a worse accessibility situation, and just a few moving from the bottom quartile (pre-pandemic) to the third during the pandemic. Those aged 18 and less appear to have fared worse, and the largest change is in the number of children who were in the third quartile before the pandemic and found themselves in the bottom accessibility class during the pandemic. These results suggest that, through a combination of the typical modes of transportation of lower income households and the spatial distribution of the population, the food bank/service locations closed had a differential impact that more greatly affected the youngest among the population in low income households.

Conclusions

Food insecurity is a significant issue for many Canadian households and while emergency and community food services can provide some relief, the COVID-19 pandemic has in all probability increased food insecurity for many

Table 2: Population at each accessibility level by age group among members households with incomes less than CAD40,000.

Accessibility Quartile	Pre-COVID-19			During COVID-19		
	Children (age $\leq$ 18)	Adults (19-64)	Seniors (age $\geq$ 65)	Children (age $\leq$ 18)	Adults (19-64)	Seniors (age $\geq$ 65)
Top 25%	2,048	7,031	3,632	1,956 (-4.49%)	6,138 (-12.7%)	3,338 (-8.09%)
Second 25%	2,190	9,631	5,023	2,365 (7.99%)	10,833 (12.48%)	5,400 (7.51%)
Third 25%	3,239	12,694	6,875	3,082 (-4.85%)	12,612 (-0.65%)	7,064 (2.75%)
Bottom 25%	3,711	13,220	7,648	3,038 (-18.14%)	11,811 (-10.66%)	6,308 (-17.52%)

Note:
Population values have been rounded.
The values in brackets for population during COVID-19 are the changes from before the pandemic.

households. To compound matters, the pandemic has also resulted in major disruptions, including to employment, mobility alternatives, and to emergency and community food services. In response, this research has sought to better understand accessibility to food banks and food service locations, as well as how the closure of some locations over the pre- and during-COVID time periods affected the potential for low-income households to reach these amenities.

Previous work has noted the important role of geography alongside other socio-economic and demographic indicators in household access to healthy food. The present papers is, to the best of our knowledge, among the first studies to focus on the geographic component of accessibility to emergency food services (Allen and Farber, 2021). Using the balanced floating catchment area method to account for population demand and congestion effects at service points, we estimated multi-modal accessibility to emergency and community food service locations for low-income households. The weighting of travel time estimates by the modal split in different zonal geographies tailors the results to patterns of travel behaviour captured in the regional travel survey. Moreover, our parcel-level analysis presents a disaggregate approach to estimating accessibility based on the locations of residential parcels and dwellings. Beyond accounting for the inflation of demand that occurs in traditional floating catchment area methods, our application of the balanced floating catchment area approach offers a novel analysis of accessibility to emergency and communal food services that is sensitive to the locations of low-income households, information on their age distributions and typical trip-making behaviour, the locations of services, their operations over time, and the characteristics of the city's multi-modal transportation network.

Our results show that while accessibility levels were lower in the city's more car-oriented suburban and rural areas to begin with, the closure of 14% of the city's emergency and community food service locations during the pandemic resulted in an overall decrease in accessibility across the city. However, these effects were not uniform over space or for different population groups. Since the balanced floating catchment area method takes into account changes in demand and congestion for service providers, the closure of some services reverberates throughout the catchment areas of the whole city. For some suburban zones, the closure of a relatively high level-of-service location results in the remaining services being spread over a larger population. In others, high auto dependence for trips leads to decreases in accessibility that accumulate due to the loss of several locations initially reachable within 15 minutes by car. Reductions in accessibility in the city's more urban north end, where low-income households conduct higher proportions of trips by transit and walking, emphasize the importance of geographic proximity in the potential to reach service locations for these residents. Beyond geography, the results also highlight the differential impact of closures during COVID-19 on population groups, with seniors and children being the two most impacted groups.

It is important to note that the degree to which our low-income cut-off of CAD$40,000 reflects food insecurity in the different zones of the study area is not known. We also consider all emergency and communal food service locations equally. Information on differential capacities at food provider locations is currently not collected, and given the closure of facilities was not possible to obtain. Data on services, such as the number of meals served, could be used to refine the analysis in the future. Moreover, while the travel survey allows us to model multi-modal accessibilities that align with travel behaviour observed in the travel survey and capture differences in accessibility by age categories, the use of travel survey data for modelling food insecurity also has its limitations. Research into the population weighting methods used in the TTS note that the survey may under-count the lowest- and highest-income households in the survey study region, although the magnitude of this under-counting is unknown, and approximately 20% of respondents to the 2016 survey did not report their income (Rose, 2018). In that regard, the modal splits of low-income households observed through the TTS data may not accurately reflect the travel behaviours of food insecure populations, and our estimates might in fact be somewhat conservative if those households who do not report income rely more on walking and/or transit for their mobility needs.

In the absence of information regarding how food insecure households travel to food banks and related services, we examined accessibility to food banks using a 15 minutes (one-way) travel time threshold. The fact that we must rely on a standard created for accessible drinking water in the developing world only serves to highlight the tragedy of food insecurity in an affluent country like Canada. More broadly, it points to the absurd need to understand how a bad situation was made worse by the pandemic: in effect, the analysis reveals that disparities in the need for emergency and community food services predated the pandemic, that the pandemic contributed to the deterioration of these services, and that populations already in distress, particularly children, ended up in an even more adverse state. How much worse, it is impossible to say, mainly because there is also a dearth of information, let alone standards, regarding *acceptable* or *sufficient* level of service when it comes to emergency food services.

While on the one hand this work suggests that inequities in the accessibility to emergency and community food services could be improved through accessibility standards that promote changes in the geographic distribution of service locations and transportation network characteristics, in fact, we would argue that the standard should be that no household faced food insecurity. As others have noted (Men and Tarasuk, 2021; e.g., Poppendieck, 1999) the root of food insecurity is income poverty and unless it is eliminated, there will continue to be a place for emergency food and community food services. In addition to providing food, these services satisfy social needs by offering a social setting for seniors or by helping to connect households in need with longer term supports. From a food security perspective, on the other hand, these services should work only as a short term solution, and not as a semi-permanent feature of life for some of our fellow human beings. From a human rights perspective, long-term reliance on emergency food services should be as unacceptable in Canada as lack of clean drinking water within 30 minutes is elsewhere. Thus, while our analysis is valuable to map the suffering caused by food insecurity, from a policy perspective, maintaining a robust social safety net that includes Employment Insurance and paid sick days are better tools to reduce this suffering than increasing the accessibility of emergency food services for food insecure populations.

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